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Embodied water consumption of biogas–digestate utilization

Chunfu Zhao, Bin Chen*, Jin Yang

State Key Laboratory of Water Environment Simulation, School of Environment, Beijing Normal University, Beijing 100875, China

Abstract

Biogas as a renewable energy has great potential to alleviate the energy scarcity and greenhouse emission pressure in rural areas. Existing studies have presented a comprehensive assessment of greenhouse gas mitigation potential for biogas-digestate utilization. However, few researches have focused on the water resource consumption of biogas-digestate utilization. In this paper, we proposed an embodied water resource accounting framework in view of the life cycle of biogas-digestate utilization. The basic inventory of embodied water consumption and accounting framework as well of biogas-digestate project was established. The applicability of the proposed framework was also discussed.

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Keywords: Biogas, LCA, Embodied water.

1. Introduction

With the rapid economic development, fossil fuel depletion and population growth, the world has been experiencing unprecedented environmental pressure and energy shortage [1]. Under such a background, renewable energy plays an important role for the sustainable energy strategies due to its environment-friendly nature. Among different types of renewable energy, biogas shows distinctive characteristics compared with other renewable sources since it is not only a high methane fuel but also an efficient use of organic waste or plant nutrients in daily agricultural practice [2]. Therefore, biogas has great potential to alleviate energy shortage in rural areas and mitigate the greenhouse emissions related fossil fuel consumption.

Life cycle assessment (LCA) as a widely accepted and applied environmental impact assessment tool can evaluate various interventions caused by human activities from cradle to grave [3]. In the context of global climate change, LCA has primarily focused on the energy consumption and greenhouse emission for a specific product or a production process. The water consumption during the production procedure, however, has received limited attentions due to the fact that LCA methodology was essentially proposed

* *Correspon*ding author. Te*l*.: +86 10 58807368.

E-mail address: chenb@bnu.edu.cn.

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and generalized by industrialized countries without suffering from water scarcity. In recent years, the escalating water crisis and the water- energy nexus have motivated a large number of studies to evaluate the life cycle water resource consumption of various renewable energies [4-6]. Regarding the biogas–digestate utilization, although the direct water consumption is small, substantial water embodied in the crop residue input and sewage of biogas may pose a great impact on water system and cannot be ignored. In this paper, we aim to propose an embodied water consumption framework to highlight both direct and indirect water consumed in the life cycle of biogas-digestate utilization.

2. Framework setting

2.1. System boundary

Fig 1 shows the system boundary on for embodied water consumption of biogas production. The life cycle stage mainly includes biogas plant construction, biogas plant maintenance, feedstock supply, biogas utilization, and digestate processing. Considering the fact that water embodied in products and service for biogas–digestate operation is much larger the direct water consumption, we mainly calculate the embodied water for the aforementioned stages in this framework. The embodied water usage can be divided into withdraw, discharge, consumption, and recycling parts. However, considering that the data of water discharge and recycling are usually unavailable, this framework primarily focuses on the water withdrawal and consumption of biogas production. The US Geological Survey has defined the "withdrawal" as the amount of water removed from the ground or diverted from a water source for use, while "consumption" refers to the amount of water that is evaporated, transpired, incorporated into products or crops, or otherwise removed from the immediate water environment [7].

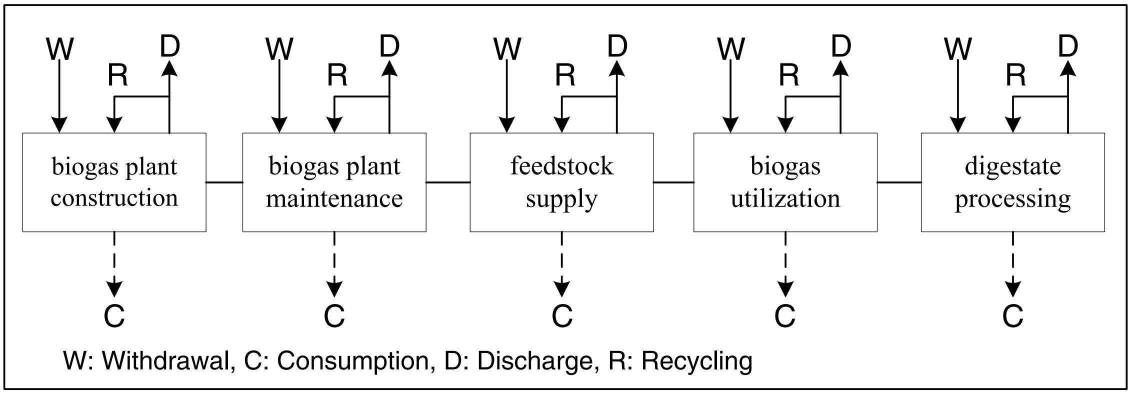

Figure 1 Water flows in the biogas production process

2.2. Life-cycle embodied water consumption inventory

2.2.1. Biogas plant construction stage

At biogas plant construction stage, water is indirectly consumed owe to the extraction and transportation of building materials for the biogas plant project. For the extraction process, the water resource embodied in the cement, rebar, red bricks, coarse and fine sand, gravel and pipelines material should be taken into account. For transportation process of these materials, water resource indirectly consumed by the transport fuel should be calculated.

2.2.2. Biogas plant maintenance stage

During the period of biogas operation, water resource consumption mainly comes from the direct compensation due to the water leakage from the reactor or treatment tanks. In addition, the material to maintain the faults should also be included in the water resource calculation for this stage.

2.2.3. Feedstock supply stage

The feedstock may differ for a specific biogas project. In general, the embodied water contained in the straw, manure, and inoculum should be incorporated into the calculation. Additionally, the indirect water resource consumption of electricity for feedstock pretreatment should be computed.

2.2.4. Biogas utilization stage

The sewage treatment from the daily life of rural residents can be purified by biogas digester in this stage. However, the digestate may pollute the underground water, so such a risk should also be considered during the inventory establishment of this stage.

2.2.5. Digestate-processing stage

Digestate-processing can be employed as a substitution for the chemical feed additives, pesticides, base fertilizers during the process of crop cultivation. If chemical fertilizer is used rather digestate, the water underground water may be polluted. Therefore, such an environmental benefit should be accounted.

3. Discussion

This paper provided a general framework for the embodied water consumption of biogas–digestate utilization. However, considering the difference of both feedstock and technology at different places, the items of embodied inventory should be adjusted appropriately. With regards to the detail accounting of water consumption, although we can refer to the work of Hoekstra et al. [8], Ecoinvent database, the challenge still existed because the water footprint mainly focuses on the agriculture products, while the embodied water for industrial products such as cement, electricity, etc., is still difficult to be calculated.

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